San Diego State University

T.A.R.S.
Target Asteroid Reconnaissance and Surveillance

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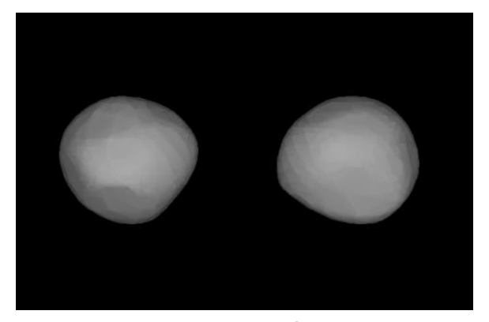
AEROSPACE ENGINEERING Advancing the Dream of Flight

TARS 2023 - 2024

MISSION PURPOSE

Asteroids hold the potential to possess valuable minerals as well as answer important scientific inquiries about the beginnings and formation of the solar system.



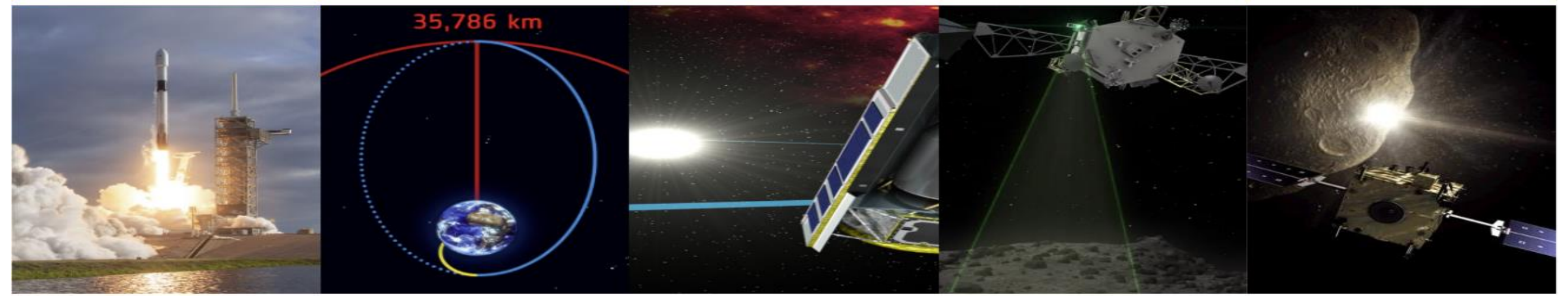
NASA rendering of the eventual asteroid choice, Flora 8

The Targeted Asteroid Reconnaissance and Surveillance (TARS) mission is a hypothetical mission to identify the composition of an asteroid. Inspired by various scientific missions and a few commercial ventures, real-world drivers restricted the budget for the mission to $20 million. The objectives for the TARS mission to complete are to:

1. Determine the ability to extract resources of an asteroid that has a diameter greater than 1 km and is of an asteroid class likely to contain high valued minerals.
2. Analyze majority of asteroid’s composition. Analyze general topography, and rotational motions.
3. Measure at least 75% of the surface’s compositional data, outline at least 30% of its surface. Obtain imaging of 100% of its surface

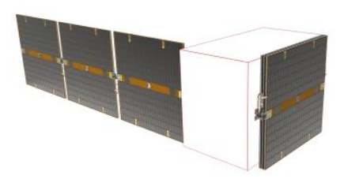
MISSION TIMELINE

Launch	Earth Centric Orbit Raise to Lunar Assist	Heliocentric Cruise Orbit	Scientific Measurement Phase	End of Life



INTERNAL SYSTEMS

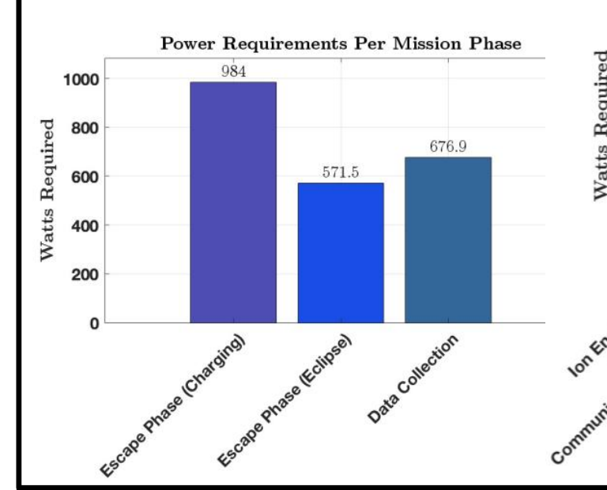
Electrical Systems

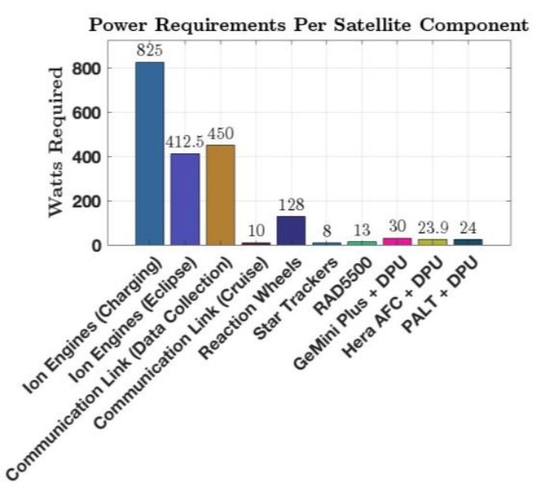


TARS will implement the Space Azur Triple Junction Solar Cells in a triple-junction setup capable of generating 1323 watts per hour.

The LP33037 - 60 Ah Cell battery will support onboard systems for extended periods of time without methods of recharging with a maximum capacity of 1080 watts.

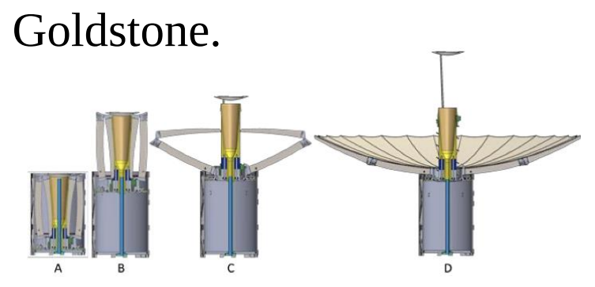
Below are the tabulated power needs of each component along with the expected power needs for each mission phase.



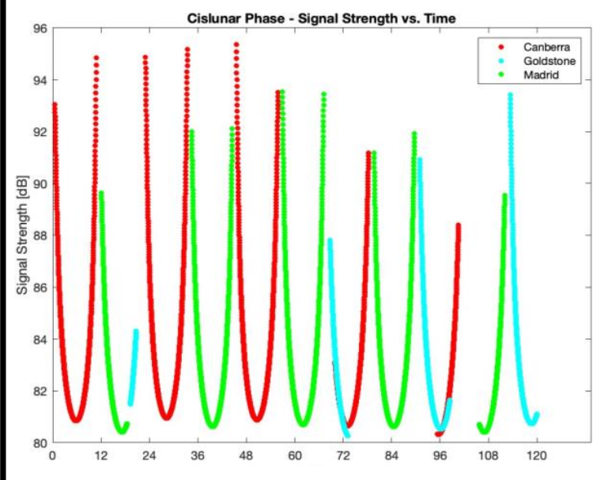


Communications

To support communication between TARS and the Earth, TARS will be utilizing NASA's Deep Space Network (DSN) ground stations located in Canberra, Madrid, and Goldstone.

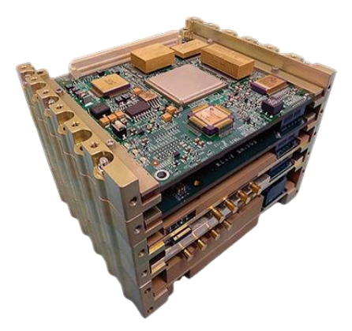


The .5-meter antenna will operate at a frequency of 21 GHz and 2000 bps.



This graph depicts the signal strength of the TARS satellite to Earth ground stations. Initially, the signal-to-noise ratio ranges from 80 to 95 dB, degrading as the satellite travels further away from earth.

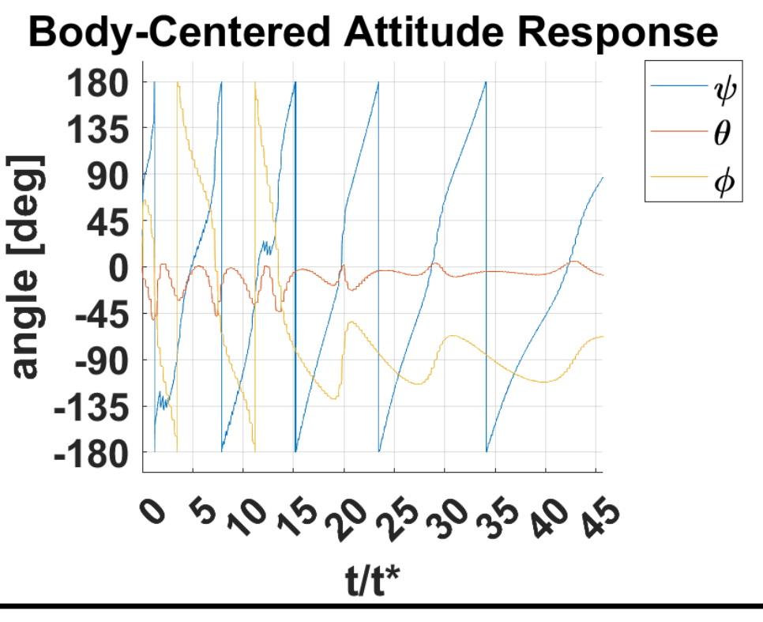
Guidance and Navigation and Attitude Control



An IRIS V2 Deep Space Transponder will be used to determine the spacecraft's position within 10 meters relative to Earth. The IRIS V2 uses the antenna to send and receive information about velocity and position from DSN.

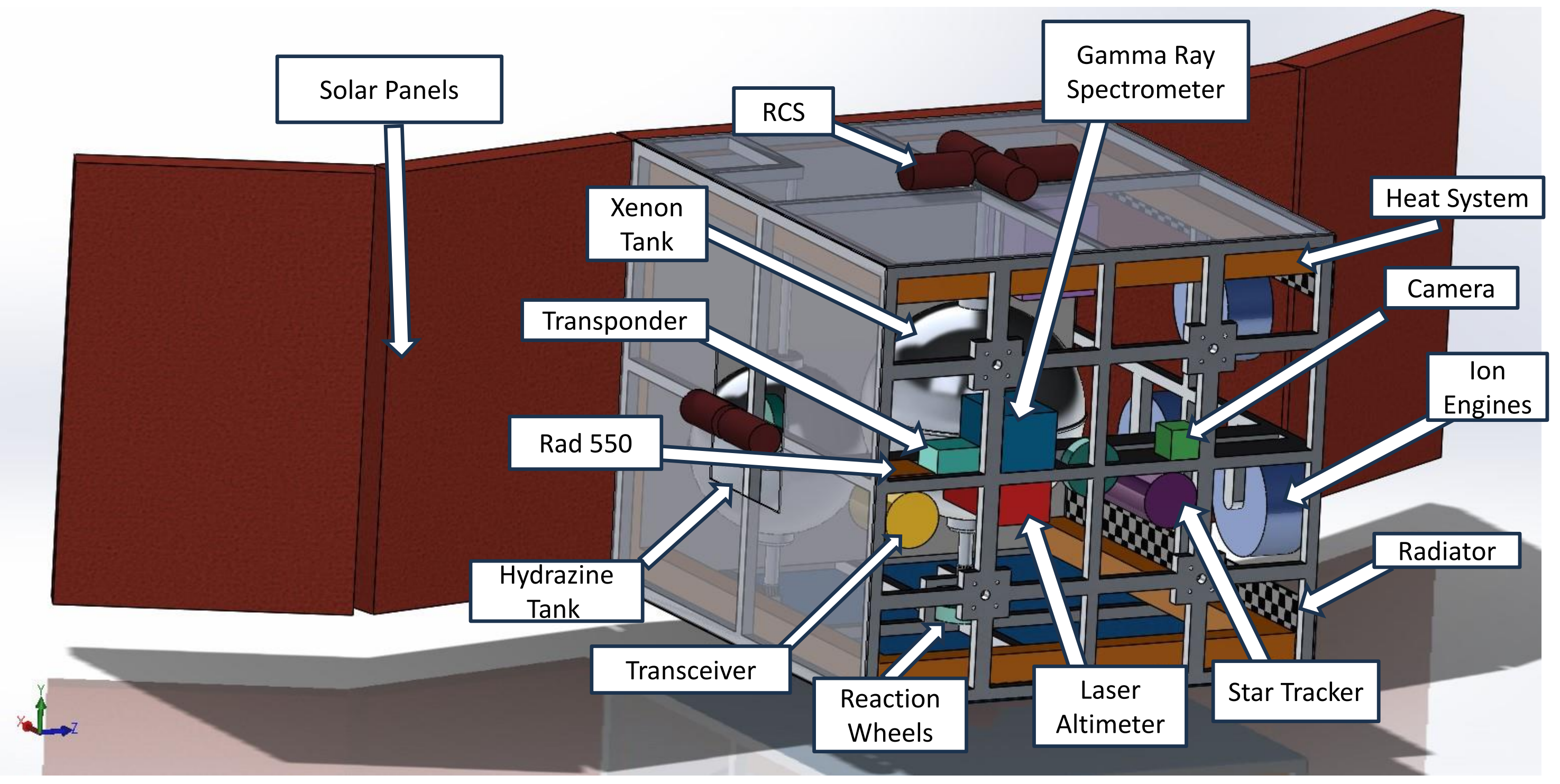
The Ball CT-2020 Star Tracker will be used to determine the spacecraft attitude within 1.5 arcseconds. The Ball CT-2020 compares images of the stars to a database of star and constellation positions. The spacecraft attitude can then be determined to a high degree of accuracy.

TARS uses the Rocket Lab reaction wheel for asteroid tracking and data transmitting.



To determine necessary thrust and orientation changes, the graph on the left was created to represent the simulated dynamic response. It is modelled in terms of its Euler angles, of TARS using four reaction wheels and a PD controller with Kp = 0.5 and Kd = 20. Angles have been wrapped to 360 degrees and the five spikes correlate to the five revolutions around the Sun during its heliocentric burn phase.

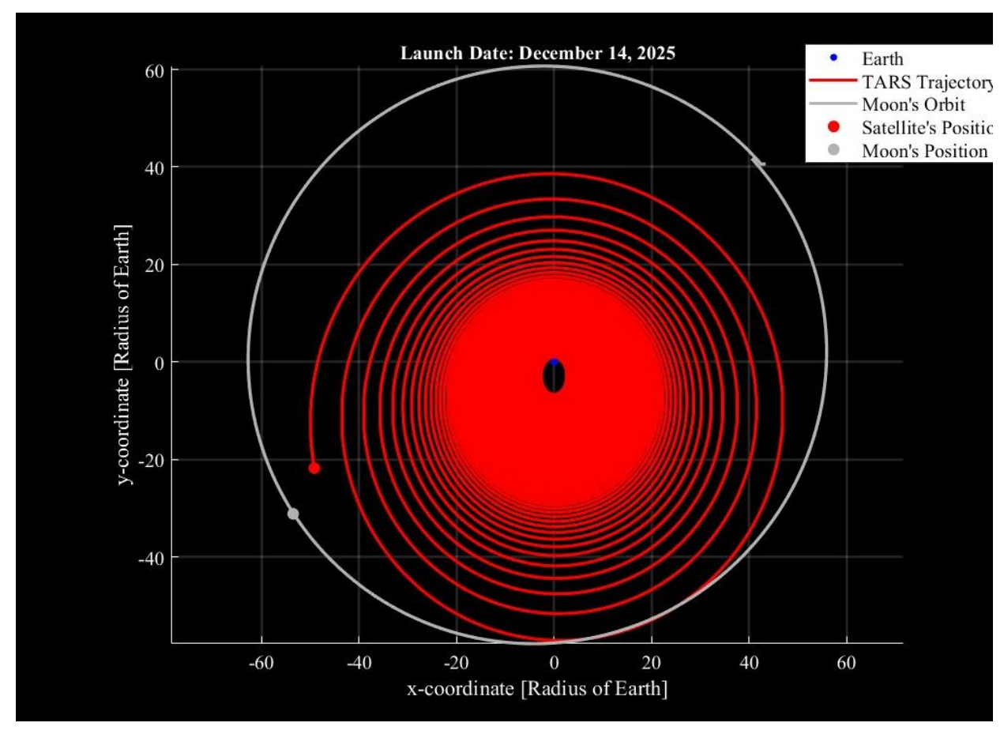
SATELLITE CONFIGURATION



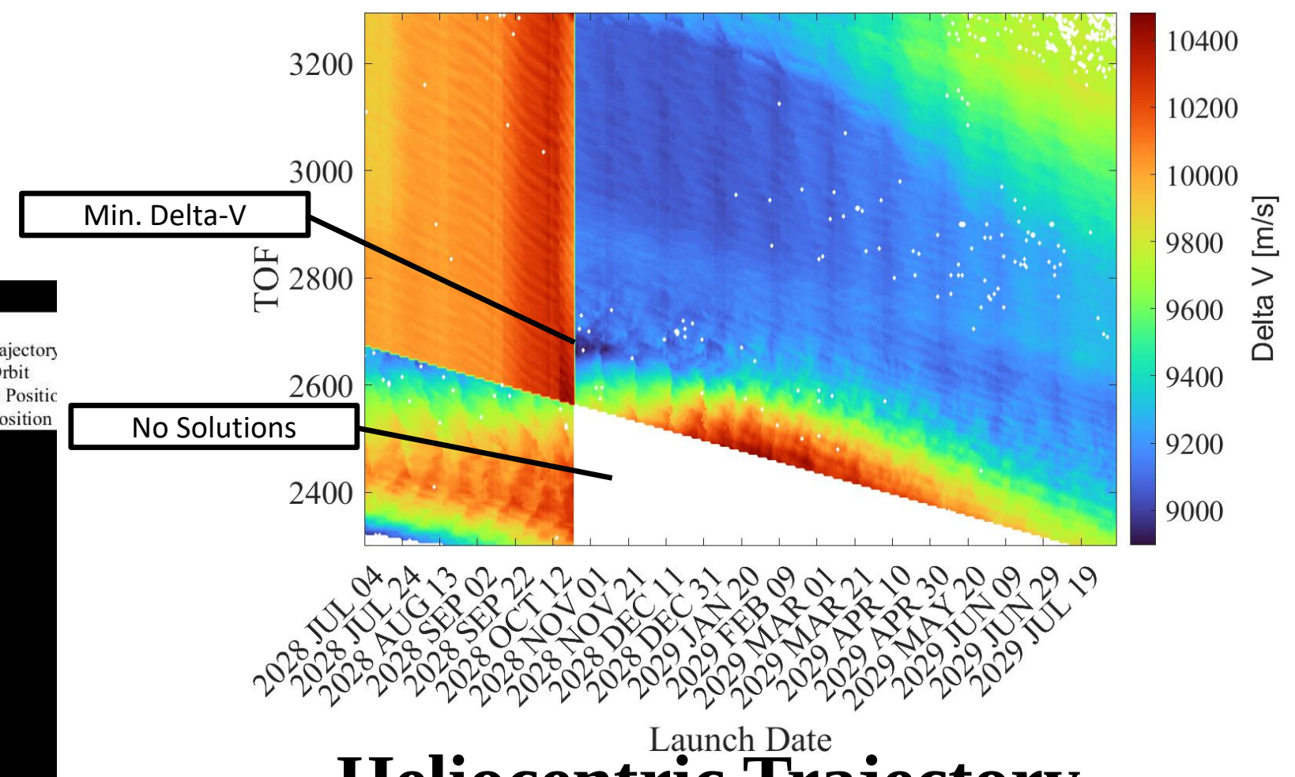
LOW THRUST TRAJECTORY

Launch Date: December 14, 2025
Fuel Expended: 243 kg
Delta-V Produced: 3236.03 m/s
Time of Flight: 27.3 months
Arrival Date: March 11, 2034

Low-Thrust Cislunar Trajectory

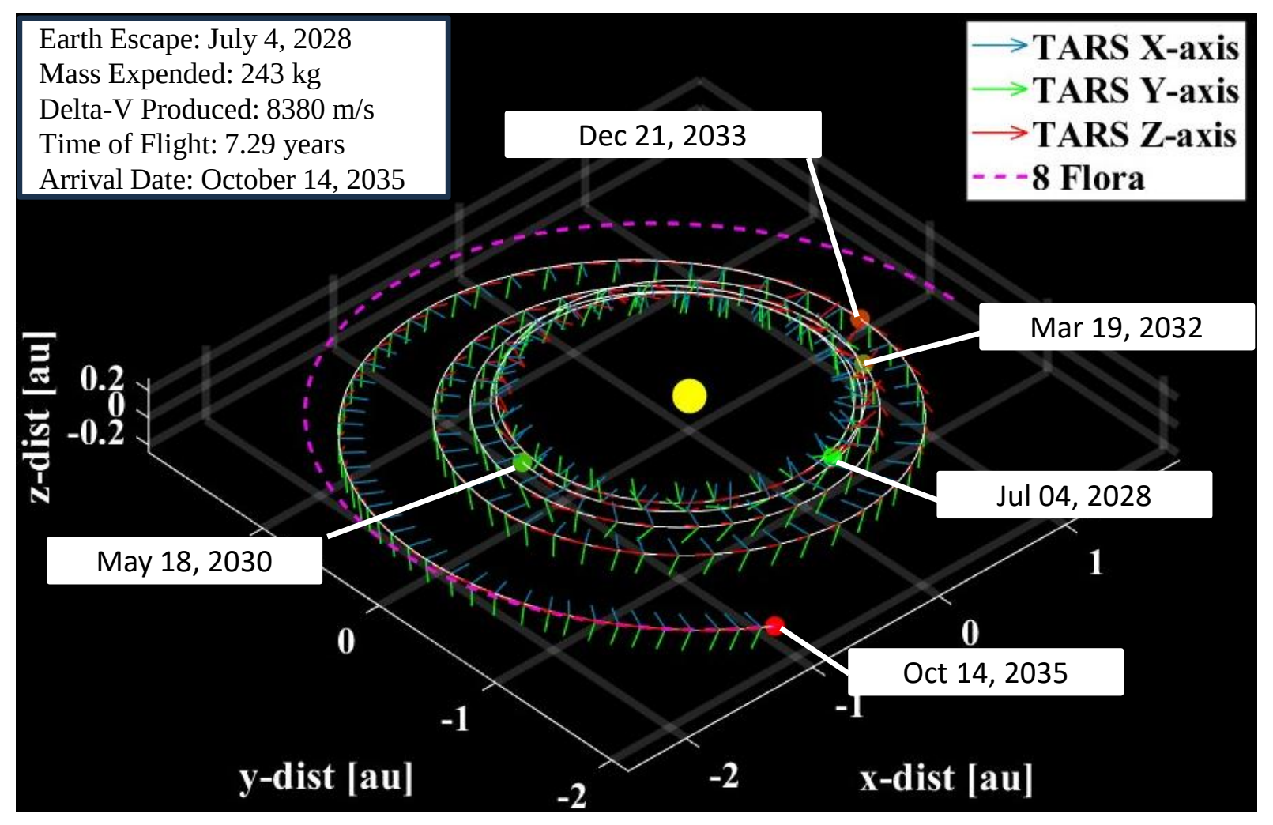


Heliocentric Porkchop Plot



Heliocentric Trajectory

Earth Escape: July 4, 2028
Mass Expended: 243 kg
Delta-V Produced: 8380 m/s
Time of Flight: 7.29 years
Arrival Date: October 14, 2035



Trajectory analysis for the TARS mission was executed with ASSET, a Python optimization tool from the University of Alabama. In conjunction with MATLAB, low-thrust porkchop plots were created to select the asteroid to reach based on mass, power, and cost constraints.

Following various trajectory studies and comparing viable targets, it was decided that Flora 8 was the most optimal target. Body-fixed orientation frames were constructed using the outputted cartesian state vectors of the trajectory.

CONTACTS

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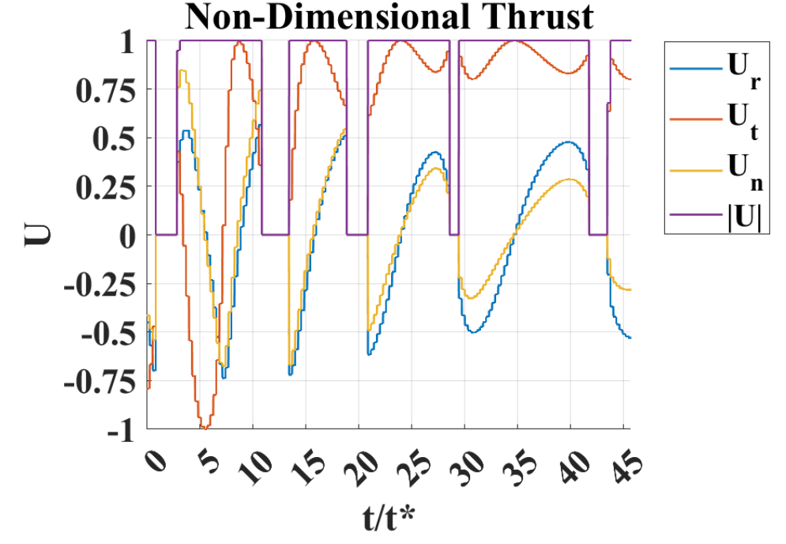
PROPULSIONS

TARS will use three NEC Ion Engines in place of traditional solid and liquid space propellants due to their ultra efficiency. While the mission time would be quite longer, for budgetary reasons, the time requirement was minorly adjusted. The mission was designed with a slight excess in fuel needs having tank storages of 275 kg of Xenon fuel for deep space maneuvers and 50 kg of Hydrazine fuel for attitude corrections.

Simulated NEC ion engines on JAXA’s Hayabusa-2 mission (left)

Ardine Group 1N Hydrazine Thruster for attitude control (right)



The above figure illustrates the non-dimensional thrust profiling that TARS will follow and execute

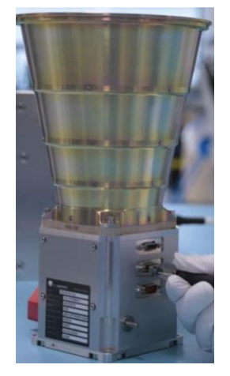
MISSION SUMMARY

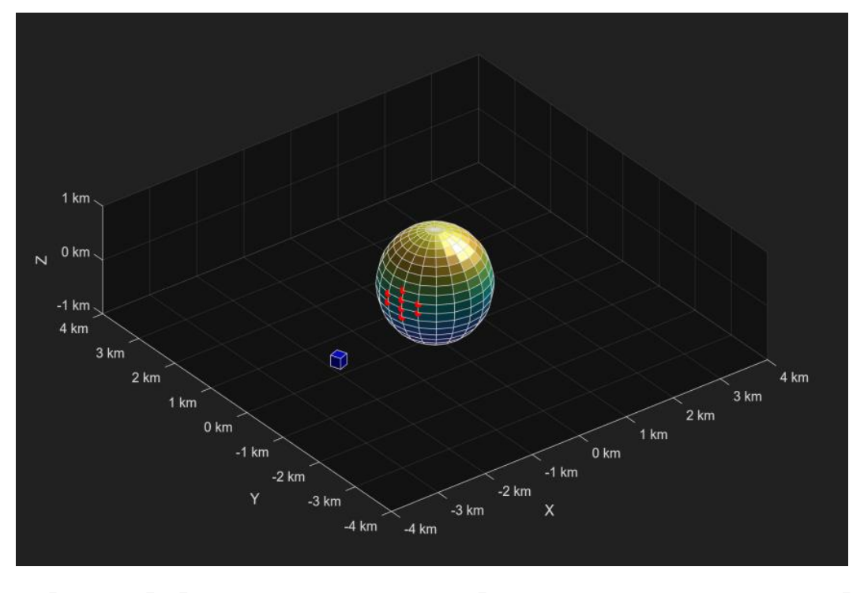
Scientific Measurements

Gamma Ray Spectrometer (GRS): GeMini Plus
Assess resource economic potential by analyzing elemental composition.

Laser Altimeter: Planetary Altimeter (PALT)
Surface assessment, shape analysis; landing site selection and navigation. Measures topographical mapping and reflectivity measurements.

Camera: HERA Asteroid Framing Camera (AFC)
Provides visual data for rendezvous and surface analysis by taking high resolution images of the asteroid.





High Fidelity GRS Simulation: To assess the performance of our spectrometer, a simulation was developed to visualize our expected coverage of the asteroid during our station keeping maneuver.

Cost, Weight and Size

Section	Cost ($)	Dry Weight (kg)	Size (cm^3)
Launch Vehicle	12000000.00		
Payload	3600000.00	5.45	8200.00
Structure	1060000.00	113.71	195000.00
Propulsions	1240000.00	22.00	10701.76
Communications	650000.00	7.10	2606.31
Power	830391.00	36.35	78325.00
DSN	1432816.40		
Total	20813207.40	184.61	294833.07
			0.67m x 0.67m x 0.66m

The cost, weight and size of the satellite was consistently tracked as the mission progressed. Displayed here are the final values of various systems considerations. The final satellite frame was determined to be 1.39m x 1.17m x 1.26m which each component fit comfortably within. The dry weight of the satellite is 184.61 kg which when fueled will lead to a total starting weight of 509.61 kg. The estimated cost is slightly over budget but is considered though is an underestimation of expected mission costs.

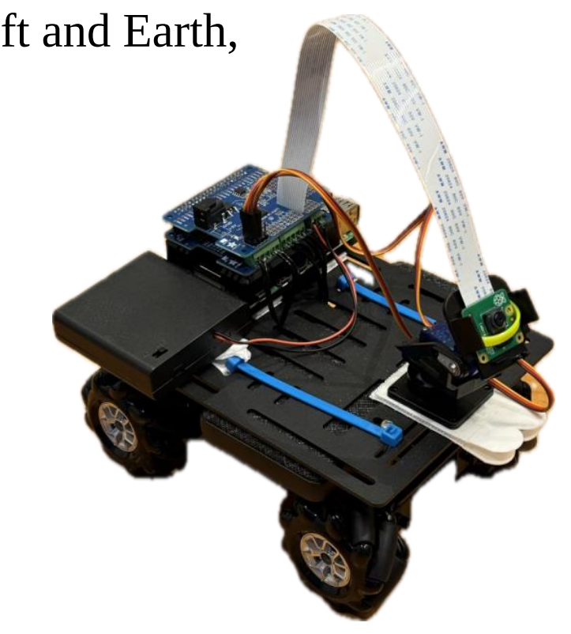
REAL WORLD SIMULATION: C.A.S.E.

Purpose
The purpose of the Camera-Assisted Surveillance Entity (CASE) robot is to physically model the TARS mission's most critical aspect: the asteroid rendezvous.

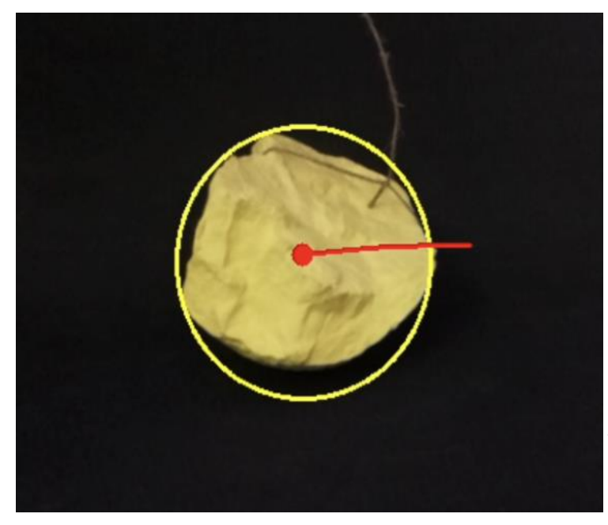
The rendezvous phase of the TARS mission will require the HERA AFC visible camera to locate the asteroid and the propulsion systems to perform maneuvers to match the asteroid's trajectory, with the attitude control system keeping the spacecraft pointed at the asteroid throughout. This phase must be performed autonomously because of communication delay due to large distances between the spacecraft and Earth,

Objectives
The objectives of the CASE robot are to autonomously perform the following:

1. Recognize a model asteroid based on color using a visible camera.
2. Point the visible camera using a 2-axis servo system, keeping the model asteroid centered in frame even with relative movement.
3. Maneuver at a specified distance from the model asteroid in an orbit -like path.



To simulate the environment in space, a rock with a yellow hue and placed against a high contrast background representing the asteroid.



Feedback Loop
A yellow-painted rock was used as the model asteroid for this experiment CASE’s CASE's onboard camera transmits live video to the onboard Raspberry Pi computer, which processes the image and recognizes the part of the frame that contains the yellow target. The 2-axis servo system positions the camera to keep the target in the center frame based on the live video. CASE itself then rotates to point directly at the model asteroid. The relative size of the the asteroid in the image is used to determine distance. CASE then moves to the specified distance from the target. An orbit-like maneuver is then executed while CASE continues to point at the model asteroid. This procedure showcases the success of each objective.